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Vestibular-Visual Interactions in Flight Simulators

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San Jose State University

SAN JOSE STATE UNIVERSITY, SAN JOSE, CALIFORNIA 95192

DEPARTMENT OF PSYCHOLOGY

VESTIBULAR-VISUAL INTERACTIONS IN FLIGHT SIMULATORS

Tenth Annual Status Report on NASA Grant No. NGL 05-046-002¹

September 1, 1976 to August 31, 1977

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INTRODUCTION

This report is the tenth annual status report for NASA-Ames Research Center Grant No. NGL 05-046-002 to San Jose State University. The report describes the work undertaken from September 1, 1976 to August 31, 1977. Throughout the period of the grant, the work accomplished has been a result of collaborative efforts between the faculty and students of San Jose State University and research scientists in the Life Sciences Laboratory at Ames Research Center. This collaborative effort has supported a substantial number of ongoing research projects being conducted in the Laboratory as well as specific experiments described in the proposal for the year. Formal research reports which have been supported by the grant and which have been published or read at meetings during the current academic year are listed at the end of this report. The experimental investigations proposed for the current academic year fell into six areas:

1. Vestibular-visual interactions.
2. Flight management and crew system interactions.
3. Peripheral cue utilization in simulation technology.
4. Control of signs and symptoms of motion sickness.
5. Auditory cue utilization in flight simulators.
6. Vestibular function: Animal experiments.

This tenth annual report will present summaries of the research work which has been completed in each of the six areas during the year as well as progress in ongoing research which has been supported by the grant.

EXPERIMENTAL PROJECTS CARRIED OUT
DURING THE ACADEMIC YEAR 1976-1977

1. Vestibular-visual interactions

Clark, B., & Stewart, J. D. The relationship between ataxia tests and other tests of vestibular function.

The purpose of this study was to determine the relationship between two ataxia tests and three other tests of vestibular function. Although there is some difference of opinion on the matter, it is commonly believed that ataxia tests with eyes closed are primarily measuring semicircular canal function with the otolith simply giving a reference to the vertical. Data derived from the following study will be analyzed to determine these relationships. A preliminary analysis of the findings on 18 men who have been tested suggests that the correlations among these tests will be low and not significant, i.e., these five tests are measuring relatively independent functions. When the data on the preceding study are finally collected, a final report will be made on the total group.

Stewart, J. D., Clark, B., Cowings, P. S., & Toscano, B. W. Changes in vestibular function following biofeedback and autogenic training to control the signs and symptoms of motion sickness.

The purpose of this study was to determine whether a training regimen designed to develop control of the symptoms of motion sickness would produce changes in basic tests of vestibular function. The training regimen is described in the study by Toscano in Section 4 of this report. In order to assess these changes, a series of two clinical and three

laboratory tests of vestibular function are being given before and after a series of biofeedback and autogenic exercises designed to control autonomic functions. The five vestibular tests are: (1) The Sharpened Romberg (Fregly and Graybiel). This test requires the subject to stand with feet placed in tandem with eyes closed, the score being the time to maintain the position. (2) Stand-on-one-leg-eyes closed (Fregly and Graybiel). This test is similar to the Sharpened Romberg with the subject standing on one leg. (3) Sensitivity to rotation is being tested using the oculogyral illusion as the indicator using a staircase procedure developed by Clark and Stewart. (4) Cupulometric measurements of the oculogyral illusion are being made using five levels of angular acceleration following a procedure developed by Dockstader at Ames Research Center. (5) The power function for five levels of angular acceleration is being measured using the oculogyral illusion following methodology developed by Elsner at Ames Research Center.

It is worth emphasizing that while simple tests of vestibular function can show unequivocally the presence or absence of vestibular function, they may not establish whether the whole vestibular system is functioning at an efficient level. Nevertheless these tests should uncover any gross changes in basic vestibular function following the training regimens. Data are being collected on 18 subjects (nine experimental and nine matched controls). Complete data are available on 13 subjects, but since the testing necessarily involves a single blind method, at this point no preliminary data are available for analysis.

Hamerman, J. A. Choice reaction time to movement of eccentric visual targets during concurrent rotary acceleration. An M.A. thesis presented to the faculty of the Department of Psychology, San Jose State University, San Jose, California, August 1977.

The present study investigated the effects of rotary acceleration on choice reaction time (RT) to an accelerating visual target. The levels of acceleration, the direction of stimulus movement, and the eccentricity were varied. Eleven pilots were tested in a rotation device under conditions of visual stimulation alone, rotary stimulation alone, and concurrent visual and rotary stimulation. The pilots were required to respond to the motion of the visual target by moving a hand controller to the left, right, forward, or backward, in accordance with the visual stimulation, and left or right in accordance with rotary stimulation, when this condition occurred alone.

The bisensory condition produced choice RTs that were no different statistically from RT to visual only conditions. The choice RTs were inversely related to level of visual acceleration and directly related to eccentricity. There was no significant difference in choice RT to horizontal and vertical movement of the dot. Choice RT to rotation alone was greater than the choice RT to either of the other two stimulation conditions. The results are discussed in regard to the effects of double stimulation on choice RT and the effects of rotary acceleration on the perception of cursors moving on a cathode-ray tube.

2. Flight management and crew system interactions

Hart, S. G. The workload assessment program being developed at Ames Research Center. Report presented at the First Triservice Operator/Crew Workload Workshop, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, April 12, 1977.

NASA-Ames Research Center's Man-Vehicle Systems Research Division has undertaken several approaches to the study of inflight workload. Studies have been made and are being conducted on voice synthesis, warning and action information systems, voice command systems, head-up displays, 3-D area and 4-D area navigation systems, fly-to systems, predictor displays, and distributed management of air traffic control. Several desirable characteristics of workload assessment measurement have been identified. Work load assessment should be unabstrusive and maintain a secondary position to the primary task; it should have construct as well as face validity; it should measure blunder-prone activities. Interviews with civilian commercial pilots suggest the following as problems: Transposing numbers and improper expectations with regard to various flight maneuvers. Investigations of various workload measurement techniques have been made with emphasis on time perception as a measurement of workload. This measurement approach is conducted constantly in flight and has high acceptibility to the pilot population. Two types of time estimation have been used: (1) active estimation which involves a constant attempt to direct time on a system basis, and (2) retrospect estimation which is based on the pilot's memory of events during some preceding time interval. Studies using time estimation techniques show that as attention increases and demands become

greater, there is a shift to shorter and shorter perception of the passage of time until they get to a point that they shift back to a longer perceived passage of time. The latter is attributed to retrospective estimation of time.

Hart, S. G., McPherson, D., & Kreifeldt, J. Multiple curved descending approaches and the air traffic control problem. A paper presented at the Thirteenth Annual Conference on Manual Control, Massachusetts Institute of Technology, June 15-17, 1977.

Several modifications of the current terminal area air traffic control system were investigated in the multicockpit ATC facility located in the Man-Vehicle Systems Research Division at NASA-Ames Research Center. The purpose was to evolve a system in which the projected increase in air traffic could be accommodated safely and expeditiously. The concepts which were investigated included: (1) a 1-minute separation at the Missed Approach Point, (2) the use of traffic situation displays in the cockpit coupled with a distributed air traffic management system, (3) multiple curved descending final approaches that merge on a common final within 1 mile of the field, and (4) parallel runways certified for independent and simultaneous operation under IFR conditions.

Three groups each consisting of three commercial airline pilots and two air traffic controllers flew a combined total of 450 approaches. Piloted simulators were supplied with computer generated traffic situation displays and flight instruments. The controllers were supplied with a terminal area map display and digital status information.

On the average, aircraft arrived at the Missed Approach Point at 64-sec intervals, which was approximately the separation set as the goal

of the task. Performance was typically better under the distributed than under the ground centralized traffic management system and both pilots and controllers felt that the distributed management system enhanced flight safety, expeditiousness, and orderliness. Pilots reported that they would prefer the alternative of multiple curved descending finals, with wider spacing between aircraft, to having closer spacing on single, straight-in finals. Controllers, on the other hand, reported that closer spacing on single straight-in finals was a preferable way to deal with increased aircraft density than multiple curved finals converging on a short, straight-in final. Both pilots and controllers felt that parallel runways certified for independent and simultaneous operation under IFR conditions, such as simulated in the present study, would be an acceptable, even desirable solution.

Kreifeldt, J. G., & Hart, S. Air traffic control by distributed management in a MLS environment. Thirteenth Annual Conference on Manual Control, Massachusetts Institute of Technology, June 15-17, 1977.

The microwave landing system (MLS) is a technically feasible means for increasing runway capacity since it could support curved approaches to a short final. The shorter the final segment of the approach, the wider the variety of speed mixes possible, so that theoretically, capacity would ultimately be limited by runway occupancy time only. The dense traffic environment resulting from efficient use of the MLS necessarily reduces the permissible response times and tolerances in the ATC system thus emphasizing the tactical aspects of traffic control. An experiment using the multiman ATC facility of the Man-Vehicle Systems Research Division at NASA-Ames Research Center contrasted air traffic

in a MLS environment under a centralized form of management and under distributed management which was supported by a traffic situation display in each of the three piloted simulators. Objective flight data, verbal communication, and subjective responses were recorded on 18 trial runs lasting about 20 minutes each. The results were in general agreement with previous distributed management research. In particular, distributed management permitted a greater number of successful approaches and both pilots and controllers perceived distributed management as the more "ideal" system in this task. It is concluded from this and previous research that distributed management offers a viable alternative to centralized management with definite potential for dealing with dense traffic in a safe, orderly, and expeditious manner.

Plans have also been developed for a second simulation study of the MLS. A research assistant with extensive experience as an air traffic controller has designed an experiment to examine some perceptual factors which affect the performance of air traffic controllers in the performance of their work if it involves the use of MLS. The experiment has been accepted as a thesis proposal by the psychology department.

Palmer, E., & Petitt, J. A measure of psychological realism on a visual simulator. Journal of Aircraft, 1977, 14, 421-422.

A fundamental question regarding simulator technology is how to determine whether an aircraft simulation is creating the proper representation of psychological space necessary to give a valid assessment of manned-system performance. This experiment is an attempt to provide a direct measure of psychological realism on a computer graphics night visual flight attachment using a well established psychophysical method

to determine the pilot's visual space perception. Specifically, the study compared angular size estimates using collimated and uncollimated visual scenes.

Fifteen pilot subjects made angular-size judgments of triangular stimuli generated on a computer graphics night visual attachment. The subjects were randomly assigned to one of three viewing conditions:

- (1) the runway seen directly on a CRT monitor with no collimating lens,
- (2) the runway seen through a collimating lens, and (3) the runway with 10-m vertical poles spaced 100 m apart along each side of the runway, seen through a collimating lens. The pilot's task was to adjust a variable size triangle by means of a joystick so that it appeared to equal a standard-size triangle in angular size. The variable triangle was always 50 m from the pilot on the left side of the runway. The standard triangle was presented twice at the following eight different distances from the pilot: 50 m, 75.0 m, 112.5 m, 168.8 m, 253.1 m, 379.7 m, and 859.3 m.

A graphic analysis of the three experimental conditions showed that perceived size varied as a function of distance in a similar manner for the three conditions of this experiment, and these were also similar to earlier findings. The "poles" conditions showed a smaller overestimation factor, the "collimated" conditions a slightly smaller one, and the "uncollimated" condition exhibited the smallest degree of overestimation. In general the perceived angular size of the standard triangle increased as a function of the distance of the standard triangle. The findings suggest that the two collimated conditions were more realistic than the uncollimated condition because the collimated conditions induced a

greater overestimation of the angular sizes of the objects.

Two general conclusions can be drawn from these results. First, collimating lenses contribute to the realism of the simulator visual scene when compared to direct viewing of a CRT display. Second, the discriminative power of this type of experiment is a useful measure for assessing the effects of hardware components and visual conditions on simulator realism.

Palmer, E., & Pettitt, J. Difference thresholds for judgments of sink rate during the flare. Journal of Aircraft, 1977, 14, 540-543.

Past studies have shown that touchdown rates of descent (sink rates) are higher in aircraft simulators than in aircraft under similar conditions. The objective of this paper was to use a psychophysical technique to investigate a pilot's ability to distinguish between two different sink rates close to the ground. The pilots observed a collimated computer graphics display of a typical runway with edge, zone, and center-line lights. The results showed that, with a forward velocity of 120 knots, pilots could distinguish reliably between a sink rate of 0.5 m/sec (1.7 fps) and 0.9 m/sec (2.9 fps). The results also showed that the absolute rate of sink did not affect significantly the perception of sink rate. Time of sink and total height drop during the sink did affect the minimum detectable differences between sink rates (the differential threshold). The effects were such that a greater time of sink and greater height drop produced lower thresholds.

Palmer, E., & Mitchell, T. The effects of photographic representation of an outdoor scene and stimulus object distance upon angular size estimation.

The two experiments undertaken in this unpublished study constitute an additional attempt to gather data on direct measures of visual space perception in simulated aircraft displays. They present additional data supporting the findings in the two published studies by Palmer and Petitt described above. Palmer and Petitt showed that angular size judgments are useful measures of visual realism in simulator displays and that outdoor cues and collimating lenses enhance angular size judgments. Experiment 1 used color and black and white photographic slides and prints under collimated conditions to determine differences between black and white and color slides in size judgments at four distances. Seven pilots with normal vision served as observers. An analysis of variance for repeated measures was performed on the ratios of perceived to actual angular size. The independent variables were: (1) color vs. black and white and (2) four distances of the standard triangle. None of the main effects nor the interactions were found to reach significance.

In Experiment 2, six pilots served as observers. Color prints were used instead of slides, but otherwise the procedure was the same as in Experiment 1. There were no significant differences among the experimental variables. Thus, the two experiments indicate that the slides and photographs were lacking in realistic information regarding the perception of distance. The following are suggested as possible factors for the lack of adequate depth perception in these materials: (1) poor photographic resolution, especially in the slides, (2) lack of texture gradients

(3) lack of adequate linear perspective, and (4) variations in target lighting due to changes in sun angle during the period of photography.

Simpson, C. A. The synthesized speech approach callout evaluation study (SYNCALL).

The purpose of this study was to evaluate the use of supplementary callouts using synthetic speech as an aid in the landing approach phase of flight. Synthesized speech messages were developed utilizing principles derived from earlier research. These synthesized callouts were used in an American Airlines Flight Academy, DC-10 simulator in Texas. The pilots who were used in the study were 20 line crews of American Airlines pilots each consisting of a Captain and a First Officer. Each crew flew approaches and landings: (1) using the standard procedure used by American Airline crews with the pilot not flying the aircraft making the callouts and (2) using supplementary callouts with synthesized speech. The data obtained included performance measures in the control of the simulator and pilot evaluations derived from a questionnaire. The data from the study have been collected, and the tapes and questionnaires will be analyzed in the coming months.

As an adjunct to the simulator study, observations have been made on some 100 approaches and landings by an observer in the cockpit of a DC-10 aircraft during regular flight operations. This made it possible to make systematic observations of normal callout procedures in order to serve as a comparison with the SYNCALL observations. Discussions of the application of the use of synthesized speech with the flight crews were also conducted. The data obtained from these observations on the flight deck will be incorporated in the report which will be prepared.

Simpson, C. A., & Hart, S. G. Required attention for synthesized speech perception for two levels of linguistic redundancy. A paper presented at the 93rd Meeting of the Acoustical Society of America, Pennsylvania State University, University Park, Pa., June 6-10, 1977.

It was hypothesized that additional contextual linguistic redundancy in the wording of synthesized speech cockpit warnings would result in less required attention for initial comprehension and subsequent recognition. Twelve airline pilots were repeatedly presented 16 unfamiliar warnings in two wording formats, key word and sentence, e.g., Fuel low compared to The fuel pressure is low. Then they heard the same warnings embedded in weather broadcast at a warning-to-weather sound pressure level ratio of +3 dB. For both listening conditions the task was to read back the message and also estimate the passage of time during message comprehension or recognition. Performance on time estimation had previously been found to correlate with hypothesized attention demands during manual tracking and aircraft simulator flying tasks. As expected intelligibility was higher and response time shorter for the sentence format than for the key word format. For unfamiliar messages, the tendency to underestimate the passage of time was greater for the two word format than for the sentence format, implying that less attention was available for the time estimation task during comprehension of messages with less linguistic redundancy. By contrast, for familiar messages there was no significant difference in performance on the time estimation task for the two levels of linguistic redundancy. Possible reasons for the difference in attention requirements for comprehension compared to recognition were discussed.

Williams, D. H, & Simpson, C. A. A systematic approach to advanced cockpit warning systems for air transport operations: Line pilots preferences. A paper presented at the NASA Aircraft Safety and Operating Problems Conference, NASA-Langley Research Center, October 18-20, 1976. Also to be published in NASA SP-416.

Fifty line pilots (captains, first officers, and flight engineers) from eight different airlines were administered a structured questionnaire relating to future warning system design and solutions to current warning systems problems. This was followed by a semantic differential to obtain a factor analysis of 18 different cockpit warning signals on scales such as informative/distracting, annoying/soothing. Half of the pilots received a demonstration of the experimental text and voice synthesizer warning systems before answering the questionnaire and the semantic differential. A control group answered the questionnaire and the semantic differential first, thus providing a check for the stability of pilot preferences with and without actual exposure to experimental systems. It was hypothesized that preferences for warning methods and cancellation method would vary as a function of warning urgency or priority and as a function of expected false-alarm rate. It was also thought that age and position flown might influence pilot preferences. There were no significant differences between the two groups for overall preferences for text and voice warnings compared to other warning methods, suggesting a high degree of stability and reliability of pilot preferences for warning methods. Warning urgency and expected false-alarm rate did produce significant differences in pilot preferences for some, but not all, warning methods. Warning urgency also produced significant differences in preferred cancellation methods for

some warning methods. Generally, the preference data obtained revealed much consistency and strong agreement among line pilots concerning advanced cockpit warning system design.

3. Peripheral cue utilization in simulation technology

Haines, R. F. Binocular summation of the peripheral retina to colored stimuli. American Journal of Optometry and Physiological Optics (To be published).

A previous study found that simple RT to flashed white stimuli imaged across the horizontal retinal meridian was significantly faster (about 35 msec at the fovea) for binocular than for monocular vision. This effect decreased with increasing eccentricity. It was also found that mean simple RT was about 15 msec shorter for binocular vision even when the response was mediated by a stimulus located beyond the visual field limit of one eye. The present investigation was undertaken to repeat this effect and to include two colored stimuli and more retinal meridians.

Six male volunteers served as subjects. All had 20/20 uncorrected near and distance visual acuity and normal color perception. The stimuli were presented on a perimeter arc and consisted of a diffused plastic lens at the exit end of which was a fiber-optic bundle. The stimuli were white, red (632 nm), and green (526 nm) and were presented tachistoscopically. The subjects' response to the light was measured by a simple RT technique. Missed stimuli were also recorded. The design included the following variables: (1) stimulus position (18), (2) stimulus color (red, green, white), (3) viewing condition (right eye, left eye, binocular),

and (4) retinal meridian (5 levels).

Binocular viewing led to significantly faster simple RT within approximately a 50° arc radius from the fovea for red, green and white stimuli. However, relatively large meridional differences were noted which appear to correspond to the degree to which the right-and left-eye stimulus retinal images overlap. Evidence for a "pseudo-summation" effect was found to occur beyond the eccentricity at which only one retina was stimulated during binocular viewing.

Haines, R. F., Rositano, S. A., & Greenleaf, J. E. Visual field collapse and intraocular pressure changes associated with gradual onset +G_z acceleration (Submitted for publication).

This study is concerned with the mechanisms which control the size of the visual field during different levels of head-to-foot (+G_z) acceleration. The specific purpose was to investigate the effect of blood withdrawal and fluid replacement upon changes in: (1) the angular width of the visual field during gradual onset of +G_z acceleration, (2) blood-flow characteristics in the temporal artery just before blackout, and (3) IOP changes after acceleration. Such information sheds light on the consequences of physiological deconditioning that results from exposure to the space environment, specifically changes involving fluid and electrolyte homeostasis and the subsequent ability to tolerate prolonged gradual acceleration in the head to foot direction during atmospheric reentry.

Six healthy young men underwent gradual onset of +G_z ($0.5 \text{ G} \cdot \text{min}^{-1}$) acceleration before and after blood withdrawal, reinfusion, and oral fluid ingestion. Changes in the angular width of the visual field

and blood flow at the temporal artery were monitored continuously up to the point of blackout. Intraocular pressure was measured before and after each acceleration run. The foveally fixated light disappeared (blackout) before the peripheral lights in 85% of the 56 runs, with mean visual field limit at about 38° (0.663 rad) from the line of sight at blackout. The mean field-of-view limit constricted at approximately 0.4° (6.98 mrad) $\cdot \text{s}^{-1}$ during the final minute before blackout for the two blood withdrawal control runs and slowed to 0.3° (5.24 mrad) $\cdot \text{s}^{-1}$ for the blood withdrawal and reinfusion runs. Mean intraocular pressure before acceleration was not significantly different than it was after acceleration, except for one blood-withdrawal run where it decreased by 1.2 mm Hg after the run.

Haines, R. F. Head-up display evaluation.

The grant has also contributed to the evaluation of head-up displays being coordinated by Dr. Haines under an interagency agreement by the FAA and NASA. The contribution consisted of the work of three graduate student research assistants who assisted in a comprehensive literature survey and a HUD hardware state-of-the-art survey which has been completed. A total of 315 technical references published since 1970 have been identified. Approximately 28% of these are review articles without substantive data; 23% were reports of laboratory work; 14% were flight evaluations; and 12% were combinations of flight and simulator tests. A user file of these reports has been established at Ames Research Center. In addition to this survey work, two of the students have developed the preliminary drafts of two thesis proposals for their masters degrees at the University dealing with HUDs. One of these deals with a cybernetics

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approach to the development of evaluation of HUDs. The other is concerned with the role of cognitive switching during the use of HUDs in a flight simulator.

Shvartz, E., Haines, R. F., Bhattacharya, A., Hodges, R., Dawson, L. M., & Greenleaf, J. E. Tilt table and exercise responses to two conditions of water-immersion, chair-rest, and bed-rest procedures (Submitted for publication).

The specific purposes of this study were twofold: To determine: (1) if the adverse effects of water immersion deconditioning, as determined by tilt table and exercise responses could be maintained on land and (2) to assess some possible causes of water immersion deconditioning. Specifically, the experiment compared the effects of a combination of water immersion and bed rest with chair-rest and bed-rest by tilt table responses and exercise tolerance before and after the treatments. Four young men served as subjects. The first procedure consisted of 8 hours of immersion in thermoneutral water (34.8°C), followed by 16 hours of bed rest (Condition A). The second procedure consisted of semireclining in a chair for 8 hours in the same position used during water immersion, at comfortable room temperature (23°C) followed by 16 hours of bed rest. Immersion resulted in twice the amount of urine loss experienced during the chair test and in lower heart rates, but urine losses were equal during the 24 hours of both conditions. While Condition B resulted in negligible and insignificant changes in tilt table responses and exercise tolerance, substantial impairment in these responses occurred as a result of Condition A. This was manifested in an increase in orthostatic heart rate and 40% decrease in tilt tolerance time, an increase in submax

exercise heart rate and 7.5% decrease in Vo_2 -max. These changes were partially related to an increase in resting heart rate which occurred in Condition A but not in Condition B, and to a larger loss in plasma volume in the first condition. The results show that water immersion deconditioning can be maintained on land in a recumbent position for at least 16 hours, and that inactivity and posture do not contribute to water immersion deconditioning.

4. Control of signs and symptoms of motion sickness

Cowings, P. S. Orbital flight tests.

In addition to her laboratory work in the control of the signs and symptoms of motion sickness and the SMD-III exercise at Johnson Space Center, Dr. Cowings has developed detailed plans to test the effectiveness of her training procedures in orbital flights. These plans include descriptions of procedures to obtain baseline data on the crews, alternative training procedures, and the evaluation of the effects of her bio-feedback and autogenic training in orbital flights. In particular, Dr. Cowings has proposed five plans for evaluating crew members' ability to apply learned autonomic control of the symptoms associated with the zero-gravity sickness syndrome. These plans consider the optimum plan to obtain data to increase the value of training on successive flights and somewhat less sophisticated plans which seem likely to lead to less useful data. No attempt will be made here to detail these plans, but it may be noted that the plan judged to reveal the most useful data would include onboard, individual, biomedical monitoring and the diagnostic motion sickness scales to be used if and when the symptoms of motion sickness

arise. Thus, several alternative plans have been proposed to give NASA management the opportunity to select the one which may be used on any particular flight.

Cowings, P. S., & Toscano, B. W. Spacelab Mission Development III. A preventative method and counter-measure for the zero-gravity syndrome: Learned self-regulation of multiple autonomic responses by crew members.

The Spacelab Mission Development III (SMD-III) refers to a simulation of a Life Sciences dedicated Spacelab mission at Johnson Space Center which was conducted jointly by NASA-Ames Research Center and Johnson Space Center. The purpose of this experiment in SMD-III was to explore techniques to reduce the symptomatology associated with the zero-gravity sickness syndrome and thereby shorten the habituation periods to zero-gravity and improve the efficiency of Spacelab crew members during projected space flights. Specifically the experimental objective was to apply a combination of biofeedback and autogenic training techniques in a simulated Spacelab situation in preparation for actual Spacelab flights.

The training phase which took place at Ames Research Center included both training in the testing procedures as a payload specialist and as a subject including the autoregulation of their own autonomic responses. Although it was not possible to produce the provocative stimulus to produce zero-gravity sickness (i.e., zero gravity as found in space flight, in either the training phase or during the simulated space flight), the exercise was planned to provide information on procedures for the actual flight experiments. The provocative stimulus used instead of zero-gravity was Coriolis acceleration produced by head movements in a rotating chair.

The effect of this provocative stimulus was monitored using Graybiel's CSSI rating scale for motion sickness and autonomic changes were monitored using continuous recording of heart rate and other autonomic responses.

The major contribution of this exercise was that it did reveal a great amount of information regarding just how such an experiment should be conducted in actual space flight. Some of these conclusions are:

- (1) Since preflight training is the crucial part of the experiment, more data are needed regarding training methods to maximize the effectiveness of learned autonomic control by the crew members.
- (2) Separate training programs must be designed for teaching the crew members who will act as "experimenters" on board the flight in methods of autonomic conditioning and reinforcing the crew members who will serve as "subjects" on the flight.
- (3) A more concise, compact package of biomedical monitoring devices is needed. The new instrument package should incorporate ease of transducer application with simplified operation to insure the collection of the required data within the time-line available during the flight.
- (4) Information was obtained on data management (and down-link) procedures which will be incorporated in future Shuttle experiment proposals.

Toscano, B. W. Bidirectional vs. unidirectional control of autonomic response patterns to suppress motion sickness symptoms in humans.

This experiment was designed to answer three questions regarding the effects of biofeedback and autogenic training on the signs and symptoms of Coriolis motion sickness: (1) Does bidirectional training produce more effective learned control of autonomic responses than training

in unidirectional control of these responses? (2) Does learned autonomic control of the signs and symptoms of motion sickness produce greater increments in performance than natural habituation to Coriolis stimulation? (3) Does learned autonomic control generalize from counterclockwise to clockwise rotation during Coriolis stimulation?

Three groups of six men each are being tested following complete physical examinations which testify to their good health. The Coriolis acceleration tests are designed to induce the initial symptoms of motion sickness conducted in a Stille-Werner rotating chair. This device is capable of achieving a maximum constant rotational velocity of 30 rpm (3.132 rad/sec). The following responses are being monitored: (1) electrocardiography derived from bipolar precordial electrodes, (2) electromyography of the external intercostal muscle derived from bipolar cutaneous electrodes, (3) galvanic skin response derived from surface electrodes located on the left index and middle fingers, (4) blood volume pulse of the hands and face, derived from photoplethysmograph transducers located on the right index finger and facial skin to the left of the mouth, and (5) respiration rate, monitored by a thermistor inserted into a nasal cavity. Feedback of the ongoing activity levels of visceral responses is presented to the subjects in visual form (wide screen oscilloscope, digital panel meters, and computer CRT) as well as in auditory form (tones and verbal feedback from the experimenter).

All subjects are given six Coriolis acceleration tests separated by 4-day intervals. Coriolis tests #1, 2, 5 and 6 will be clockwise rotation while Coriolis tests #3 and 4 will be counterclockwise rotation. These tests consist of initiating rotation (around the subject's own

vertical axis) at 6 rpm (9.628 rad/sec) and incrementing by 2 rpm (0.035 rad/sec) every 5 minutes. The maximum rotational velocity is 30 rpm (3.142 rad/sec). During each 5-minute interval at a constant rotational velocity, subjects execute 120 head movements at 45° (.79 rad) angles in four quadrants. Instructions for direction of head movements (random order at 2-sec intervals) are presented using a tape recording. A diagnostic scale devised by Graybiel, the Coriolis Sickness Susceptibility Index, is used to determine subject's malaise levels.

The subjects were divided into two groups, one high susceptibles and the other low susceptibles during a selection phase of the experiment. Three experimental procedures are being used: (1) training using bidirectional rotation, (2) training simply to produce parasympathetic responses on all trials, and (3) no training. Susceptibility was measured in terms of the number of rotations achieved by the subjects. Complete data have been collected on 13 subjects, and when the data on the remaining five subjects are collected, a formal report will be forthcoming as a masters thesis at the University.

Toscano, B. W., & Cowings, P. S. Autogenic feedback training for autonomic response patterns: A comparison of pattern feedback vs. individual response feedback.

This experiment was an exploratory study whose purpose was three-fold: (1) It served as an initial investigation into the generalization of learned autonomic control across stimulus conditions (clockwise Coriolis acceleration, counterclockwise Coriolis acceleration, linear acceleration, and optokinetic stimulation). (2) An attempt was made to document within-subject differences in symptom onset (i.e., determine if

there are pronounced differences in individual response stereotypy within autonomic response patterns of a subject) across these stimulus conditions. (3) Methods of improving current training procedures were studied. To this end, two groups of men were taught autogenic-feedback training procedures (to control heart rate, respiration rate, and peripheral blood volume), but they differed in the types of feedback they received. One group was presented with a feedback array providing information about the current state of each of these autonomic responses. The other group received only one feedback signal, indicating that all three of these responses were at their optimal levels or below the median heart rate computed on the subject's own baseline data. Optimal level of peripheral blood volume pulse was defined as producing a degree of vasodilation at or greater than the median level computed on the subject's own baseline data. Optimal level of respiration rate was defined as breathing at a frequency of 13 to 17 breaths per minute and with consistent volume.

The analysis of the data computed thus far reveals: (1) Symptom onset within-subjects differed considerably across stimulus conditions (with regard to relative time of occurrence of symptoms and their severity) but individual response stereotypy was prevalent. (2) Of the stimulus conditions tested, Coriolis acceleration was the most provocative while optokinetic stimulation was the least provocative of motion sickness symptoms. (3) Those subjects participating in posttraining tests showed a reliable improvement in performance (final statistical analysis of the significance of improved performance is now in progress) providing evidence that learned autonomic control can indeed generalize across stimulus conditions. Subjects who received only one feedback signal

appeared to learn more quickly than those presented with a feedback array, but at the end of twelve training sessions (.5 hour each) both groups had achieved a comparable degree of learned autonomic control.

5. Auditory cue utilization in flight simulators

In the audio simulation project, design specifications have been developed for a research quality, auditory simulation facility. Several tasks have been accomplished during the current reporting period. Hardware and software have been developed by Dr. Barnebey that will allow the Hewlett-Packard 2108 computer to control, in real time, a General Radio 1/3 octave band spectrum shaping system. Thus, it is currently possible to dynamically shape a broad band noise source in real time to represent a nonstationary noise such as those found in aircraft cockpits. A three-axis controller has also been procured and connected to the HP 2108 computer by Dr. Barnebey through a multiplexed A-D conversion system. With this system it is now possible to simulate pilot control influences on the generated noise characteristics, e.g., changes in power settings. Finally, a Fast-Fourier Transform program has been made operational on the HP 2108 computer that makes it possible to analyze actual aircraft noise signatures and will thus facilitate the development of noise models to be used with the aforementioned hardware system.

6. Vestibular function: Animal experiments

McCarty, M., & Daunton, N. G. Vestibular and visual effects on postural responses of pigeons. A paper presented at the Western Psychological Association Meeting, Seattle, April 21-24, 1977.

Interaction of vestibular and visual sensory information is experientially commonplace. Seeing a moving train through a stationary train window or watching a Cineramic movie scene are visual situations associated with illusions of self-movement. The primary sensory mechanism for self-motion is the vestibular system of the inner ear which is sensitive to angular and linear motion. In investigations of vestibular and visual interaction, evidence for linearvection (the sensation of linear self-motion created by linear visual motion) has been shown in human psychophysical studies and animal neurophysiological studies. The purpose of the present study was to determine whether animal subjects would experience linearvection.

To determine whether linearvection exists in pigeons, postural adjustments of unrestrained pigeons on an instrumented perch were measured under two conditions of sinusoidal linear motion: (1) self-motion as the pigeon cage was oscillated back and forth past the striped visual-surround and (2) visual motion as the striped visual-surround was oscillated past the pigeon. A pen recorder was used to collect output from accelerometers on the table and visual stimulus, and from the strain gauge built into the perch. Ten naive pigeons were tested under the motion conditions of: (1) self-motion and (2) visual motion. Additional sessions were run with a solid red visual stimulus. In response to sinusoidal linear self-motion and striped visual motion, postural adjustments

of the pigeons were sinusoidal, in phase with the stimulus, and showed no measurable latency. When the visual stimulus was solid red, there was no corresponding sinusoidal response. The regularity and persistence of the pigeons' postural adjustments to visual motion indicates that linearvection exists in pigeons. However, while the empirical model for human linearvection has a 15-sec onset latency, there was no latency in pigeons' postural response. The most plausible explanation for latency differences is that the latency found in human psychophysical studies is a measure of choice time and not of actual onset of the phenomenon. The postural reflex measure may be a more sensitive measure for onset. Absence of sinusoidal postural response for the red visual condition suggests linearvection is related to visual stimulus features.

Thomsen, D. D., & Dauntan, N. G. A neurophysiological basis for visual illusions of linear self-motion. A paper presented at the Western Psychological Association Meeting, Seattle, April 21-24, 1977.

Illusions of self-movement as a result of interactions between motion-sensing (vestibular) and visual system inputs have been of particular concern due to their role in motion sickness and disorientation. Investigated in this experiment was evidence for a neurophysiological basis specifically for illusions of linear self-movement. Such evidence may give useful information which could be used in solving the problem of motion sickness and disorientation in air and space flight and in aircraft and automobile simulators.

Single units in the vestibular nuclei of chronic cats, relaxed with Flaxedil and artificially ventilated, were tested for sensitivity to linear accelerations by moving the subject on a table in fore-aft, right-

left, and up-down directions with a stationary visual stimulus encompassing the frontal and peripheral visual fields of the subject. This stimulation was given in the dark, to obtain data solely from the vestibular system, and in the light to obtain data from both the vestibular and visual systems.

Finally, movement of the visual stimulus in the aforementioned directions was provided while the subject was stationary, to obtain data from the visual system only.

Analysis of the response of 57 single units showed that the majority of cells which respond to linear acceleration also respond to linear visual stimulation in such a manner as would be appropriate for illusions of linear self-movement. That is, a unit which responds to the subject moving to the right also responds to the visual stimulus moving to the left. Also, unit activity was modified in response to the combined visual and vestibular input as compared with the unit's activity when responding to either the visual or vestibular stimulation alone.

Such findings provide a neurophysiological basis for self-movement illusions, such as those found in psychophysical and behavioral studies and motion sickness induced by interacting visual and vestibular stimuli. Further, the efficacy of antimotion sickness drugs can be assessed by observing the effects of these drugs on the single units in which the visual/vestibular interactions are known to occur.

PUBLICATIONS AND PAPERS READ AT
MEETINGS DURING THE
ACADEMIC YEAR 1976-1977

1. Cowings, P. S. Human factors in aerospace research. Paper given at the meeting of the Ninety-Niners, Inc. San Francisco, California, August 19, 1977.
2. Cowings, P. S., Billingham, J., & Toscano, B. W. Learned control of multiple autonomic responses to compensate for the debilitating effects of motion sickness. In: W. Luthe, & F. Antonelli (Eds.), Therapy in psychosomatic medicine. Autogenic therapy. Roma: Stampato dalle Arti Grafiche Tris, 1977.
3. Cowings, P. S., & Toscano, B. W. Psychosomatic health: Simultaneous control of multiple autonomic responses by humans. A training method. In: W. Luthe, & F. Antonelli (Eds.), Therapy in psychosomatic medicine. Autogenic therapy. Roma: Stampato dalle Arti Grafiche Tris, 1977.
4. Cowings, P. S., & Toscano, B. W. Theory of the evolutionary significance of psychosomatic disease. In: W. Luthe, & F. Antonelli (Eds.), Therapy in psychosomatic medicine. Autogenic therapy. Roma: Stampato dalle Arti Grafiche Tris, 1977.
5. Daunton, N. G., & Thomsen, D. D. Otolith-visual interactions in single units of cat vestibular nuclei. Neuroscience Abstracts, 1976, 2, (Part 2), 1057.

6. Haines, R. F. Binocular summation of the peripheral retina to colored stimuli. Accepted for publication by the American Journal of Optometry and Physiological Optics.
7. Haines, R. F., Rositano, S. A., & Greenleaf, J. E. Visual field collapse and intraocular pressure changes associated with gradual onset +G_z acceleration. (Submitted for publication).
8. Halloran, T. O., Clark, B., & Stewart, J. D. Reaction time to accelerating lines and dots on a cathode-ray tube. (Submitted for publication).
9. Hamerman, J. A. Choice reaction time to movement of eccentric visual targets during concurrent rotary acceleration. Paper read at the Spartan Psychological Association Meetings, San Jose State University, May 5-6, 1977.
10. Hamerman, J. A. Choice reaction time to movement of eccentric visual targets during concurrent rotary acceleration. M.A. thesis, San Jose State University, San Jose, California, August, 1977.
11. Hart, S. G. The workload assessment program being developed at Ames Research Center. Report presented at the First Triservice Operator/Crew Workload Workshop, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, April 12, 1977.
12. Hart, S. G., McPherson, D., & Kreifeldt, J. G. Multiple curved descending approaches and the air traffic control problem. A paper presented at the Thirteenth Annual Conference on Manual Control, Massachusetts Institute of Technology, June 15-17, 1977.

13. Kreifeldt, J. G., & Hart, S. G. Air traffic control by distributed management in a MLS environment. Thirteenth Annual Conference on Manual Control, Massachusetts Institute of Technology, June 15-17, 1977.
14. McCarty, M., & Daunton, N. G. Vestibular and visual effects on postural responses of pigeons. A paper presented at the Western Psychological Association Meeting, Seattle, April 21-24, 1977.
15. Mitchell, T. Development of a measure of aircraft simulator visual fidelity. Paper read at the Spartan Psychological Association Meeting, San Jose State University, San Jose, California, May 5-6, 1977.
16. Palmer, E., & Petitt, J. A measure of psychological realism on a visual simulator. Journal of Aircraft, 1977, 14, 421-422.
17. Palmer, E., & Petitt, J. Difference thresholds for judgments of sink rate during the flare. Journal of Aircraft, 1977, 14, 540-543.
18. Shvartz, E., Haines, R. F., Bhattacharya, A., Hodges, R., Dawson, L. M., & Greenleaf, J. E. Tilt table and exercise response to two conditions of water-immersion, chair rest, and bed-rest procedures. (Submitted for publication).
19. Simpson, C. A., & Hart, S. G. Required attention for synthesized speech perception for two levels of linguistic redundancy. Journal of the Acoustical Society of America, 1977, 61, 7.
20. Simpson, C. A., & Williams, D. H. Pilot preferences for the design of future cockpit warning systems. Invited paper presented at the meeting of the International Air Transport Association, Ames Research Center, February 24-26, 1977.

21. Simpson, C. A., & Williams, D. H. Increased response time associated with an alerting tone before synthesized voice warnings during a simulated approach and landing study. Invited paper presented at the meeting of the International Air Transport Association, Ames Research Center, February 24-26, 1977.
22. Thomsen, D. D., & Dauntun, N. G. A neurophysiological basis for visual illusions of linear self-motion. Paper presented at the Western Psychological Association Meeting, Seattle, April 21-24, 1977.
23. Williams, D. H., & Simpson, C. A. A systematic approach to advanced cockpit warning systems for air transport operations: Line pilot preferences. A paper presented at the NASA Aircraft Safety and Operating Problems Conference, NASA-Langley Research Center, October 18-20, 1976. Also to be published as NASA SP-616.